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Plusminus: Level Design for Emergent Gameplay

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Emergent gameplay occurs when the rules of a game system interact and create new behavior that is not defined by the rules of the system. It has been a widely discussed topic in the research of games and game design, and it is described as a desirable and beneficial property of a game system that is difficult to design. Emergent gameplay has been described to increase player freedom and creativity, make game worlds more consistent and immersive, increase the depth and strategy in games, and extend the lifespan of a game. However, it may also make designing games more difficult, decrease the creative control of game designers, and enable game-breaking behaviors.

Previous research on how to design games for emergence has approached the topic heavily from the perspective of technical implementations of the game rule systems. In this thesis emergent gameplay is approached from the perspective of level design, and the impact of level design on the occurrence of emergence in a game is discussed. The thesis states that designing games for emergence requires considerations in level design of the game, and that level design decisions can significantly increase the emergent properties of a game system. The thesis looks into previous research on emergence and analyzes the definitions of the concept. The findings are then used to form several methods and approaches on level design in order to support and encourage emergent gameplay which are used to design levels for an action-puzzle game Plusminus. Finally, the thesis discusses the methods and approaches formed and evaluates the results of the attempts to increase emergent gameplay through level design.

The conclusions of this thesis suggest that how levels are designed can introduce constraints in emergent gameplay and that the occurrence of emergence and use of emergent strategies in games can be improved with level design solutions.

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Emergenssi viittaa pelitutkimuksessa pelijärjestelmän toimintaan, kun järjestelmän säännöt ovat vuorovaikutuksessa ja luovat uudenlaista käyttäytymistä, joka ei ole järjestelmän sääntöjen määrittelemää. Aihetta on tutkittu paljon pelitutkimuksessa ja -suunnittelussa, ja se mielletään usein toivottavaksi pelijärjestelmän ominaisuudeksi, jota on vaikea suunnitella. Emergenssin on väitetty lisäävän pelaajan vapautta ja luovuutta, tekevän pelimaailmoista todentuntuisempia ja immersiivisempiä, lisäävän peliin syvyyttä ja strategisuutta sekä pidentävän pelin käyttöikää. Se voi kuitenkin tehdä pelien suunnittelusta vaikeampaa, vähentää pelinkehittäjän kontrollia pelaajan pelikokemuksesta ja mahdollistaa peliä rikkovia toimintoja.

Aiempi tutkimus pelien suunnittelusta emergenssille on lähestynyt aihetta usein näkökulmista, jotka ovat painottuneet vahvasti pelijärjestelmän sääntöjen tekniseen toteutukseen. Tämä tutkimus lähestyy emergenssiä peliympäristöjen suunnittelun näkökulmasta ja analysoi ympäristösuunnittelun vaikutusta emergenssiin. Tutkimus esittää, että pelien suunnittelussa emergenssiä varten on emergenssi huomioitava myös pelien ympäristöjen suunnittelussa ja että pelien ympäristöjen suunnittelulla emergenssin esiintymistä voidaan lisätä merkittävästi. Emergenssiä lähestytään aiheena analysoimalla aiemman tutkimuksen sille antamia määritelmiä, minkä pohjalta luodaan peliympäristöjen suunnittelumalleja emergenssin lisäämiseksi toimintapeliin Plusminukseen. Lopuksi käytettyjen suunnittelumallien käyttöä ja vaikutusta emergenssin esiintymiseen arvioidaan.

Työn tuloksista voidaan nähdä, että pelien ympäristöjen suunnittelu voi luoda rajoitteita pelaamiselle, mikä voi myös vaikuttaa emergenssin esiintymiseen. Tulokset myös viittaavat siihen, että emergenssilähtöinen peliympäristöjen suunnittelu, ainakin Plusminuksen kaltaisessa pelissä, voi lisätä mahdollisuuksia emergenssin esiintymiseen.

Avainsanat:	Julkaisukieli:
Pelisuunnittelu, emergenssi	English

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1 Introduction

Games are set apart from other medias, such as movies, music, or books, by them being interactive. Progression in movies and books is linear and fixed, and the person watching or reading has no impact on the pace or direction of the narrative. Interaction, which allows such control, characterizes games and provides them a unique nature. In a game of Tetris, the player can freely choose their actions within the rules of the game. They can choose where to place the next game piece and in which orientation, and they can often speed up the game by increasing the falling speed of a piece. The player has an impact on how long the game lasts and what is the outcome of the game. In a book, the same events happen always and in the same order no matter how many times the reader reads the book or how much they desire to change the outcome.

Using or consuming games is referred as play. Salen and Zimmerman defined play as "the free space of movement within a more rigid structure" [1]. A game provides the player a pool of actions they can perform, and play would refer to the freedom of the player to choose actions from the pool. Watching a movie or reading a book allows only one action, watching or reading respectively, and therefore would not be considered as play.

The level of interaction and play may vary between games. *Super Mario Bros.* allows the player roughly to move, jump, and collect items in the game world. The game's progression, however, is strictly defined by the game world (the player cannot choose freely in which order to play the levels) and the rules (the player cannot return to explore earlier levels). *Minecraft* allows the player to freely move, jump, and collect items in the game world, and additionally freely explore any aspects of the world, shape the environment, build buildings and contraptions, and more. Minecraft's possibility space, the set of possible actions for the player [1], seems to be larger than the possibility space of Super Mario Bros.

Sometimes, games may extend the possibility space by designing the game so that it allows interactions between separate actions or rules resulting in a second order consequence that is different from the outcome of either individual action [2]. For example, a game can allow the player to perform actions such a jumping and setting up an explosive. The two actions might be combined into setting up an explosive on the ground and jumping on it when it explodes, which in a physics-based game might result in the player reaching higher than they would reach with only either action alone. This may be referred as *emergence* or *emergent gameplay*. It describes behavior or events in a game which derive indirectly from the rules of the game system as the rules interact and create dynamics that may not have been anticipated by the game designers [3].

While emergence is widely discussed in game design research, the discussion is almost entirely focused on game system and mechanics design and implementation. However, mechanics alone often do not enable emergent gameplay since the player needs an open environment which provides them opportunities for exploration of the game world and the game system in order to emergence to occur. For example, Smith and Smith [4] used a candle falling into an oil puddle as an example of emergence in games. In the example game, candles were defined with a "fire" property, and oil had "flammable" property. As an example of emergence, the player could cause an impact on where the candle was standing, causing the candle to fall and set the oil puddle on fire, damaging nearby enemies. However, what is not mentioned is that the game environment also needs to provide concrete scenarios where candles and oil puddles can exist or can be brought together in the same space. Additionally, if the oil puddle and the candle are set intentionally next to each other or the environment layout is set so that making the candle fall seems like an obvious (or maybe the only) outcome, many aspects of emergence may not be present no matter how the game system and mechanics might support it. This leads to the main thesis of this research:

Designing games for emergence does not involve only game system design but requires also considerations in level design, and that level design may have significant impact on how emergence occurs in a game.

This thesis discusses emergence in games from the perspective of game level and environment design. It is linked with a project to design an action-puzzle game which encourages emergent gameplay. The next chapter will go deeper into the current research on emergence in games and discuss the theoretical background of the topic in further detail. In the third chapter the game project is shortly described, and the paper will discuss level design techniques used in the project in order to support and encourage emergent gameplay. The results are also evaluated through playtesting observations. In the final chapter, the paper will summarize the results introduced in the previous chapter and discuss their meanings and directions for future research. The development process of the game project is also outlined. Additionally, the limits of the research and the project are reflected on.

This research is done together with a game design project for which the author worked as a game programmer and level designer, approaching the topic of emergence from both the perspective of game mechanics implementation and the perspective of game level and environment planning. The goal of the project was to create a game which would be designed to support and encourage emergent gameplay. The game is called Plusminus. It is a physics-based action-puzzle game and the main mechanics revolve around the player manipulating the magnetic properties of various game objects. Many objects in the game environment can be given either negative or positive polarity, after which objects of same polarity will apply repulsing force to each other and objects of opposite polarities will attract each other. At the

time of this paper, the game is around one hour long and includes around twenty rooms with either puzzle or action challenges. This paper approaches the topic of emergence and level design from the perspective of Plusminus in terms of genre and other technical details relating to game development. Additionally, the paper discusses emergence mainly from the perspective of level design. Game system and mechanics design is out of the scope of the paper, and instead of discussing how to create systems that allow emergence, the paper focuses on how to design environments for an existing physics-based system that enables and supports emergence.

2 Background

Next, the core concepts of this research will be introduced and the previous research on the concepts is analyzed. The first part will aim to define the basic concepts of a game and game design, from where the focus moves to the definitions of level design. Finally, the chapter will examine the previous research done of the concept of emergent gameplay.

2.1 Game Design

Before discussing level design, the chapter will look into game design in general and into the different aspects of it. Game design research is still a young field of study, so it is useful to define what is meant by the design of games. In his book, Schell provides an intuitive definition for game design: "*game design is the act of deciding what a game should be*" [5]. It describes well the idea of what is the goal of game design and establishes it as a field of design. However, it does not address some of the more complicated nuances related to the design of games specifically. If we examine games as artifacts, it is reasonable to say that the game designer decides what a game will be. Yet, because of the non-linear, interactive nature of games, it is important to also examine games as experiences. The game experience for one game is different for each player of the game and predicting how the experience will be like is never fully possible [1]. Especially when the paper later discusses emergence in games, it becomes essential to understand that game design does not define how the game experience will be like, but only provides the player tools and directions for it. The actual game experience will depend on individual players and the different contexts in which the game is played. Therefore, the definition of game design by Schell is not sufficient for the purposes of this paper, since it proposes a definition for a game which is conflicting with the concept of emergence, which is an essential topic for this research.

It seems that before defining what is game design, it is necessary to look shortly into how to define the basic concept of **a game**. One early definition for game by Suits, an American philosopher, states that a game is an activity where one attempts to voluntarily reach a specific goal by unnecessarily inefficient means [6]. The definition already defines game as an activity instead of as an artifact, which fits better the topic of the research of emergence. It also seems to cover most if not all types of games. However, the definition is very broad and raises questions relating to some contexts which are typically not considered games but might still match Suits' definition. For example, using the definition, would a walk to the grocery store be a game if walking was chosen instead of other faster, more efficient means? Game researcher McGonigal discusses the Suits' definition further and proposes four defining traits for a game: a goal, rules, a feedback system, and voluntary participation [7]. Using this model, the grocery

store walk example can be examined further. Reaching the grocery store provides *a goal*. Getting closer to the store functions as *a feedback system*. Walking instead of driving seems to match the *voluntary participation*. The only one remaining would be *rules*, but one could argue that the traffic system and general etiquette, traffic lights and walking on the right side of the street, impose additional rules on walking. Traffic may actually have some elements that would allow it to be considered a game in a philosophical sense. However, the definition is still too broad and impractical for the purposes of this research.

In their book *Rules of Play: Game Design Fundamentals* [1], Salen and Zimmerman did a comparison of game definitions proposed by several scholars. Almost all the definitions defined a game through the activity or the experience of playing a game. Based on the comparison, they formed their own definition of game which will be used for this research as well:

> *A game is a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome.*

The definition describes a game as a system defined through the action or use of the system. This perspective on games is more suited for the later discussion on emergence in this research and it also introduces some important terminology which will be discussed later in this chapter. Salen and Zimmerman also propose a useful definition for **game design** stating that game design is a process by which a game is made by a designer to be encountered by a player whose actions in the game create meaningful consequences in the game system [1]. The consequences of player's action will become a crucial topic when emergence will be defined later.

Before examining level design and emergent gameplay, two important concepts, game mechanics and gameplay, have to be still described. **Game mechanics** often refer to the actions a player can make in a game. Lundgren and Björk define game mechanics as a part of the game rule system that covers one, and only one, kind of interaction in the game [8]. Such interactions are for example trading with other players, negotiation, or rolling a die and moving. Hunicke et al. define mechanics in a similar manner, stating that "mechanics are the various actions, behaviors and control mechanism afforded to the player within a game context" [9]. In digital games, mechanics and the game's content such as levels and art assets, form the overall game structure.

Lastly, since emergent gameplay is one of the core topics of the research, a short definition of the concept of **gameplay** is necessary. Since play refers to the use of games, intuitively gameplay could be misunderstood as synonymous to playing a game. Instead, gameplay refers to the low level and interactive aspects of the game system and often does not include everything that forms the overall game experience, like the story or narrative properties of the game [10] or the visual appearance [11]. Gameplay is the interaction between the player and the game system that occurs when the player experiences the game through playing [1].

2.2 Level Design

Level design, a subset of game design, refers to the process of planning and designing environments, maps, missions, and stages for games [12], which are referred as levels. According to Kang, compared to game design, level design does not attempt to create systems but to implement systems into game experiences [13]. In Super Mario Bros., level design would refer to the placements of blocks, enemies, pits, coins, platforms, and other game objects in each level or area of the game. In Tetris, it could refer to the pace of the increasing difficulty and how it affects gaining higher score in the game. Since there is high level of diversity in game types and genres, level design is difficult to define across the whole field of games. However, in this research the perspective is limited mostly in 3D games of the action-puzzle genre. In this context, level design refers to building the environments and designing the puzzles and challenges of the game.

Level design may include tasks that are essential and directly defining the game experience of the players. According to Bleszinski, a level designer is, to some extent, responsible of the final presentation of the different aspects of the game, such as art assets or the behavior of an artificial intelligence agent, and has to evaluate in their work what aspects of the game create pleasant game experiences [14]. Similarly, Rollings and Morris argue that level design should focus on showcasing the game's merits [15], and Kang describes level design as a composite role which brings together art, design, and engineering [13]. While artists may create 3D models for characters and the environment and programmers design the behavior of the characters and mechanics, still the final placement, presentation, and the interaction space for the assets fall into the domain of level design. From this perspective, level design may be one of the most direct methods to impact the player's game experience in digital games.

Salen and Zimmerman [1] discuss the notion of game rules and how game rules may define the identity of the game system. Non-rule characteristics of a game can be changed, and the game system could essentially stay the same. For example, a game of Tic-Tac-Toe could be played with colored rocks, or with figures representing dogs and cats, but the game system would still play the same.

Rules in digital games are thought to be something the programming code of the game represents, if not being even synonymous with it [1]. However, rules and code are separate properties of a game, since code contains many features of the game that are not rules. For example, the visual representation of the game environment, or how and when the game audio and music is played, involves often a lot of code but may not have any impact on how the game rules are played out.

More importantly, from the level design perspective, the programming code might not include everything that determines how the game system works. For example, if the rules of Super Mario Bros. were written down, it would be necessary to mention that if the player falls in a pit,

the character dies. This behavior might be implemented in the game programming code where the character's position is checked. However, what if all the levels in the game were created so that pits do not exist in the game at all? While the rule about falling in a pit is still implemented in the code, from the point of view of the players of the game it does not make sense to list that as one of the rules of the game. Super Mario Bros. could also even now include features no one except the creators of the game is aware of, and there would be almost no way to learn about these features without consulting the creators themselves.

How the game environment is designed can have significant impact on what Salen and Zimmerman call constitutional rules of a game [1]. These rules describe behaviors and logic that derives from other rules of the game. For example, the geometrical properties of a Tic-Tac-Toe grid define some strategies and characteristics of the game, which are not directly understood from the rules. Or in Plusminus, the sizes and layouts of rooms may define what strategies are efficient when fighting enemies and which strategies are not.

This discussion of level design and its role as a part of game rules becomes more important when examining emergent gameplay. Emergent gameplay is usually considered as something that emerges from game rules. However, for example in Plusminus emergent gameplay is often enabled or supported by the properties of the game environment which were defined by the level design process. Similarly, emergent behavior which could be theoretically possible from the game system's point of view might not be possible to occur because of level design decisions. It seems that the role of level design in defining the rule system of the game is not clear and defining its impact for emergent gameplay would require further discussion.

2.3 Emergence

Next chapter will discuss emergence, often synonymously referred as emergent gameplay, and look into previous research and definitions of the concept. In games, emergence is often used to refer to various game system behaviors that occur as a result of game rules interacting with each other. For example, in Plusminus the player might use magnetic forces to apply an upward force to an object they are standing on currently, giving them a high upward momentum and enabling them to reach elevated areas they could not otherwise reach. What makes this example emergent is that the behavior is not stated by the game rules, but it is a result of the interactions between rules describing magnetic forces and general kinematic physics simulations.

As a concept, emergence is older than the field of video game design research itself, and it can be useful to look into the study of emergence outside of the field of games to gain further insight into the concept. In 1926, decades before the first video games, Pepper discussed emergence from the perspective of philosophy [16]. He described emergence as "what emerge are not laws, but what the laws describe". This idea applies in game design as well. In the

context of game design, the statement can be understood that emergent gameplay is not something directly defined by the game rules, but something that arises from the rules. After all, games are essentially systems and concepts and theories related to the research of systems may provide useful insight into understanding games as well. In fact, in his book Dormans argues that it is useful for game designers to understand emergence in other systems than games, since emergent gameplay in game research refers to the same concept as emergence in the research of non-game systems [17]. Additionally, Fromm suggests that it might not be possible to understand emergence when examining the concept from the perspective of only one related field [18]. He describes emergence as a concept difficult to explain with models or theories because of how it produces new and unpredictable results. Fromm proposes the following definition for **emergence** which will be used in this research as well:

> *A property of a system is emergent, if it is not a property of any fundamental element, and emergence is the appearance of emergent properties and structures on a higher level of organization or complexity.*

Considering the age of the whole field, emergence is fairly well researched topic in game design research. In 2001, Smith discussed the design of Deus Ex, an action role-playing game, and defined emergence as something that occurs in a game but could not be simply inferred from the game's rules [19]. According to him, "emergent behavior occurs when a system acts in an organized fashion beyond the sum capabilities of its individual parts". As an example of emergence, he presented a playtesting finding. In Deus Ex, players could attach proximity mines on different surfaces in the game. The game also included basic 3D movement and jumping controls. This allowed players to attach a proximity mine on a wall, jump on the top of it, then attach a second mine slightly higher on the wall and jump on the top of it, enabling the player to climb any walls up. The example highlights some of the important aspects of emergence in video games. It allows the player to find creative ways of playing the game, which the game designer might have not designed or be aware of at all. The player is given more control on the events of the game and their actions have more accurate consequences in the game world. However, it may also be game-breaking, as in the case of proximity mine climbing, and may result in decreased quality of game experience [20].

Juul discussed emergence in video games and its definitions further in 2002 [21]. He presents emergence as one of two types of structures of games, emergence and *progression*. While progression is a model typically found in adventure and story-based games where actions and events in the game are predetermined and the game follows a linear and controlled structure to the end, emergence is a set of smaller rules that interact with each other, resulting in a large number of game variations. In games of emergence, players also tend to form strategies and organize tournaments. Additionally, Juul criticized that game designers sometimes consider emergence simply as player behaviors or situations in a game that were not planned or

predicted by the game designers. Such a definition is little use for academic research since it is difficult to know when something in a game had or had not been predicted by the designers of the game. Juul also criticizes Smith's example of proximity mine climbing, stating that it is too simple and easily derived from the rules of the game to be considered as emergent gameplay. However, Juul's argumentation why the proximity mine climbing example would not be considered as emergent gameplay may deserve similar criticism that he gave to the confusing usage of the term emergent gameplay by game developers. The concept of emergence becomes difficult to discuss and research if its definition required the evaluation of how difficult a behavior is to derive from the game rules and whether the behavior or event exceeds an arbitrary level of complexity to be regarded as emergent. Clearly, there is some uncertainty of how easily the proximity mine climbing example is to derive from the game rules of Deus Ex since the game designers had not predicted it themselves. And despite whether it is easy or difficult to derive from the rules, it matches Fromm's definition of emergent property since it is not directly defined by the game rules.

As with Juul's study, it seems that emergence in games is often considered as one extreme of a continuum. According to Sweetser and Wiles, a continuum from emergence to *scripting* can be used to describe games and development of games [3]. Scripting refers to the implementation of interactions in a game where each interaction is individually defined, similarly to the structure of progression introduced by Juul. For example, the interaction between a glass of water on a counter and fire in a fireplace could be defined to result in the fire extinguishing. However, the same glass of water might not work on another fireplace or any other fire unless the developers specifically link the glass of water with it. Additionally, if the developers add another glass of water somewhere in the game, they would have to define the interaction of the glass with every fire in the game if they want to keep the interaction between glasses of water and fire consistent through the game. As an opposite of scripting, emergence would refer to defining general interaction rule between water and fire so that anything the game considers as water will extinguish anything the game consider as fire. This allows interactions and behaviors that were not planned by the developers to occur. For example, if the game rules define only the general rule that water extinguishes fire, the player could find a bucket of water to put out a candle even if the developers never thought about it, as long as the game considers the bucket of water as water and the candle as fire.

Similar to the studies as emergence opposed to progression and emergence opposed to scripting, Church describes the concepts of *simulation* and *emulation* [22], where the former is closely related to emergence. In game design, he describes simulation as a design approach where actions are implemented by creating the rules that result in the desired outcome, and emulation as a design approach where actions are implemented by imitating the desired outcome. In a case example of implementing jumping in a game, simulation would refer to creating a rule system where an upward force is applied on the object after which continuous downward force, gravity, would limit the jumping height and ensure that the object falls back

down. Emulation, however, would be more similar to for setting the position of the object to match the position of the desired outcome the duration of the jump. Use of simulation results in more flexible systems that can allow emergent behavior, while use of emulation results in one type of rigid behavior. However, Church emphasizes that simulation can become difficult to implement and becomes extremely complex fast. He also adds that simulation does not necessarily lead to improved game experience, and emergence alone is not fun nor provide gameplay.

Often, research seems to consider emergence as something that is very integral part of games. In the cases of emergence as an opposite to progression, emergence as an opposite to scripting, and simulation and emergence as an opposite to emulation, emergence is considered as one end of a continuum, and some form of it probably does exist in most games. For example, according to Juul, emergence occurs in card games, board games, most action games, and all strategy games [21]. He also considers player-formed strategies generally as emergence. In game research, it is also not uncommon for game researchers to discuss different properties of games which upon closer inspection would actually fall into the definition of emergence. In 2004, Hunicke et al. introduced one of the first formal frameworks for understanding game design and structure, titled the MDA framework [9]. The framework highlights three different components of games: models, dynamics, and aesthetics. Interestingly, the definition of the dynamics component is very similar to the definition of emergence. The framework describes dynamics as:

> *Dynamics describes the run-time behavior of the mechanics acting on player inputs and each other's outputs over time.*

The mechanics are described as the data representation and algorithm level components of the game, which can be also considered as the rules of digital games. However, while the description of dynamics seems similar to emergence, some examples of dynamics in the paper imply that the concept refers to components of higher-level abstraction. Some of the example dynamics presented in the paper are time pressure and opponent play. Emergence, however, is often thought to be at the same level of abstraction as the rules of the game, as in the example of proximity mine climbing. At the same time, examples of emergence in other research include also behaviors of higher-level abstraction such as bluffing [1], which is also used as an example dynamic for the MDA framework. There seem to be a clear overlap between the concepts of dynamics and emergence, which raises the question of what the difference between the concepts is or are they essentially the same. After all, time pressure may not be what game designers usually think when discussing emergence, but since time pressure is not something that rules define but it emerges from the introduction of a time limit rule, it does match the definition of emergence.

While emergence is often discussed in positive light, it may also result in decreased game experience or in game-breaking behavior. For example, Purho discussed emergence in his talk about the development of Noita, a game with heavy emphasis on emergent systems [23]. The project required large efforts in tuning the game system before the emergent behavior provided any value for the game experience of the players. In earlier development versions of the game, player actions in the game would often start chain reactions of effects that would spread extremely fast and make the game first chaotic and eventually result in uninteresting stable game states. For example, starting a fire would result in the fire spreading until all game environment would catch fire and eventually end up destroyed and in ashes. Salen et al. also describe this problem with emergence [1]. They introduce four different type of state systems depending on how the system changes its states based on its previous state. Fixed systems stay always the same, periodic systems repeat same sequence of states, chaotic systems change from one state to another without any causality between the two states, and emergent systems have more complex rules to move from one state to the next. While the example of Noita might seem like a chaotic system at first, it does not necessarily fit the definition of a chaotic system but matches better with the definition of an emergent system. However, from the player's perspective the system seems chaotic because after the beginning the player's impact on the events is minimal and understanding the causal relations between different events in the game becomes too difficult.

The unpredictable nature of emergence can make it difficult to design for from the game development point of view. Sweetser and Wiles argued that emergent systems can require significant amount of initial planning and system design from the beginning, since often the rules have to be defined in advance [3]. Emergent systems may require additional abstract layers of relations between different components of the game. For example, in a non-emergent system, a rule that a glass of water can be broken with the bullet of a gun is simple to implement, but in an emergent system the same rule might require several rules: a glass of water is breakable, the bullet of a gun is breaking, and breaking objects can break breakable objects. While this requires more work for the single behavior of a bullet breaking a glass, the rule does not need to be repeated for every two-object relation, but it is enough to set objects either breaking or breakable. In a non-emergent system, the designer would define the interaction rule between each object pair, and it would be impossible for the player to find any interactions that were not intentionally implemented by the game designer. Additional to the system design perspective, emergent games can also require a lot more efforts in playtesting and quality assurance compared to games where emergence is not emphasized [3]. Since emergence causes often unpredictable results, testing has to cover as much different types of players and styles of play as possible for the developers to understand the possible game-breaking behaviors and other issues caused by emergence in the game. Getting the emergent properties to achieve desirable results requires also often large efforts in balancing and tuning

[24]. Finally, emergence often also leads to decreased level of creative control for the game designers, because of the unpredictable and open nature of emergence [3].

However, despite the difficulties and issues emergence can introduce into game development and design processes, it is often regarded as positive and desirable property of a game. Sweetser and Wiles described how emergence can help the game world to feel consistent and therefore more immersive [3]. The way emergence enables dynamic interactions between objects in the game can make it feel more natural and logical. Consistency of the world can also make the game more intuitive and easier to learn, especially if the emergent properties of the game world match the properties of the real world [25]. For example, if fire can burn everything that seem flammable, and thus matches the real-world behavior of fire, the player can apply their knowledge from the real world into the game without having to relearn it. If instead the fire would burn only certain arbitrary objects, the player would need to learn which objects can be burnt and which cannot. Additionally, emergent games provide the player a level of agency and freedom that non-emergent games may often lack [21]. Game design for emergent gameplay focuses on providing the player freedom and choice of impacting and interacting with the game system and to create outcomes that were not intentionally set for the players by the game designers [20]. It provides a certain degree of player creativity. Emergent games often allow more player-created strategies and techniques that may at times prove even too efficient considering the pacing and challenge designers had intended for the game [21], like for example the earlier example of proximity mine climbing. Finally, compared to scripted games [3], games with the progression structures [21], or games made using emulation [22], the unpredictability of emergence can greatly extend the lifespan and the replay value of a game [1].

Finally, before closing this chapter, the perspectives and approaches on how emergence is discussed in game design research is examined. The discussion on emergence has often a technical nuance. Technological or algorithmic principles such as cellular automata, flocking, and neural networks are common topics of the research of emergence and often used as examples on how to introduce emergence in games [2]. Smith introduced the concept of systemic level design for designing emergent behaviors in games, yet he focused on the technical implementations of level elements and the interactions between them [20]. Instead of level design itself, he argued that higher-level abstraction layers for the interactions between objects enable emergent gameplay. In their paper, Sweetser and Wiles also describe emergence as a way to implement game content or gameplay structures in a game [3]. Both scripted games and emergence games refer to the way game content structures are formed, but not how the content itself is created. Smith and Smith discussed the same approach in their presentation [4]. They provided an example where in a game, the dynamic interactions between tables, oil puddles, and candles can enable emergent behavior and strategies such as throwing an object towards a table, which will make a candle on the top of the table to fall down in an oil puddle below the table, making the oil puddle to catch fire and therefore

damaging any enemies near the table. Such behavior is possible because of the interactions between all the different game objects are made possible with careful planning of the technical implementation of the general game object structures. However, is this all that was done for the emergent behavior to occur? The perspective that seems to be often absent in the research on video game emergence is the level design aspect which is less related to the game code or engine implementation. While in the previous example proper designing of the game engine and implementation is necessary in order to enable the emergence, the actual scenario would have never happened unless the game objects were decided to be set so that the interaction is possible, for example by placing them in the same area of the game. Additionally, the emergent behavior would occur considerably less often if the candle, the table, and the oil puddle were positioned far from each other.

The next chapter will look into the ways how the level design of Plusminus attempted to encourage and support emergent gameplay. The chapter will describe the ideas on how the level design could support emergence, the approaches that were used to lead the player towards emergent gameplay, and the practical techniques and examples of how it was done.

3 Level Design for Emergence

In this chapter, the practices on how emergent gameplay was attempted to be supported in the level design of Plusminus are discussed in detail. The aim is to demonstrate how level design decisions can impact the occurrence of emergence. The chapter will have a more concrete approach on the practices used in the game for the purpose of increasing emergent behavior. Six approaches or methods used in the level design are described and evaluated shortly. Some of the methods were used from the beginning of the project, and some were formed only during the project through playtesting observations or design discussions.

Before discussing level design, the basic gameplay of Plusminus is summarized. Plusminus is a 3D action game viewed from a third-person view. The player can move freely, jump, and control the camera view around the character. The game also includes double-jump, which means that the player can jump in mid-air once before landing on ground.

The player can also magnetize objects, which means sending a magnet flying towards where the camera is pointing at the time. When the magnet collides with anything, it will either magnetize a metal object or create a temporary magnetic field on a non-metal surface, depending on which one it hit. Magnetizing a metal object means assigning it one of the two polarities, positive or negative, and the player controls which polarity they assign to the object. The object will turn either red or blue, depending on the polarity, and a same-colored partially transparent field will appear around the object indicating the interactive range of the magnet. When two magnetic fields of magnetized objects overlap, magnetic forces are applied on the objects depending on the polarities. If both of the objects have the same polarity, the objects apply repelling forces on each other. If the objects have different polarities, the objects apply attracting forces on each other. If one the fields was created on a non-metal surface, it is not affected by magnetic forces, but it can apply forces on other objects.

This concludes the basic mechanics of the game. The player and any dynamic objects in the game environment are affected by the physics engine, and the puzzles of the game are based on the interactions of the magnetism system and the physics engine. In combat, player generally uses magnetic forces to damage enemies. Every enemy is a metal object that can be magnetized and colliding other enemies or objects in them inflicts damage on them. Enemies can be also defeated by removing them from the game area, making them fall in bottomless pits, or making them collide with walls, the floor, or the ceiling. Enemies are also able to damage each other, and the player can use this for their advantage.

The basic structure of the game is quite linear. The player starts in a room, where they can move to the second room. The second room involves a simple puzzle, which has to be solved for the player to progress to the third room. The game allows the player a choice of two paths

twice during the game, but other than that the game follows the same linear structure. Rooms usually include either a puzzle or a combat scenario in addition to areas that have the only purpose of traversal from one room to another. In this, Plusminus resembles what Juul describes as games of progression, as opposed to games of emergence [21]. However, while games often seem to struggle in balancing progression level structures and emergent gameplay, the two are not exclusive [17]. Classifying games simply to games of progression or games of emergence may dismiss some of the internal structures of the games.

The game levels in Plusminus will be referred with numbers and names listed in appendix A. The levels from *1.1 Anteroom* to *1.10 Final* refer to the spring 2018 version of the game, and the levels from *2.1 Tutorial* to *2.14 Final* refer to the most recent version at the time of publishing this research. The levels of the most recent version of the game are divided in four parts. The first part functions as an introduction to the mechanics for the player and includes levels from *2.1 Tutorial* to *2.5 Hub*, including a single forking path with the player being able to choose between the levels *2.3a Floor* and *2.3b Conveyor Belts*. The second and third part provide the player two paths starting and eventually leading back to the *2.5 Hub* level, and players can choose to do them in either order. The path from *2.6a Tower* to *2.11a Planet* includes levels that are heavily focused on emergence, while the path from *2.6b Experiment Room* to *2.11b Acrobatics* focuses on a level style that is closer to the concept of scripting by Sweetser and Wiles [3], emulation by Church [22], and the progression structure by Juul [21]. The last part from *2.12 Train* to *2.14 Final* involves a couple of levels of a higher difficulty level before the end of the game.

3.1 Problem-centered Puzzle Design

In order to enable the players to find their own emergent solutions to the puzzles in Plusminus, the puzzles were designed in a way that placed as few requirements on how the player would need to solve it as possible. Instead of focusing on what the player should do in order to progress, the focus was on what state the player should achieve, or what are the victory conditions for the individual level. In practice, this was done by making the puzzle goals as simple and to contain as few different stages as possible. For example, the goal might be that the player has to reach an elevated area, or that the player has to cross a pit in order to progress in the level, or that the player has to defeat all the enemies in the room. While levels are designed in a way that they provide the tools and, if necessary, hints for at least one solution, the game attempts not to set expectations on how the player solves puzzles and aims to support even unforeseen solutions.

For this, a “design problems, not solutions” approach was often used. Several levels in the game, such as the *2.11a Planet* and *2.8a Pool*, were especially designed purely from this point of view. The first level involves a large floating magnetic sphere the player falls on and they

need to reach the walls of the room without falling down, seen in the figure 1. The latter level has a door at the bottom of a pool filled with magnetic objects preventing the player from accessing the door. Both of the levels started as problems without set solutions, but the solvability of the problems was only confirmed through playing the level itself. Interestingly, the two levels did also get comments about being interesting and novel.

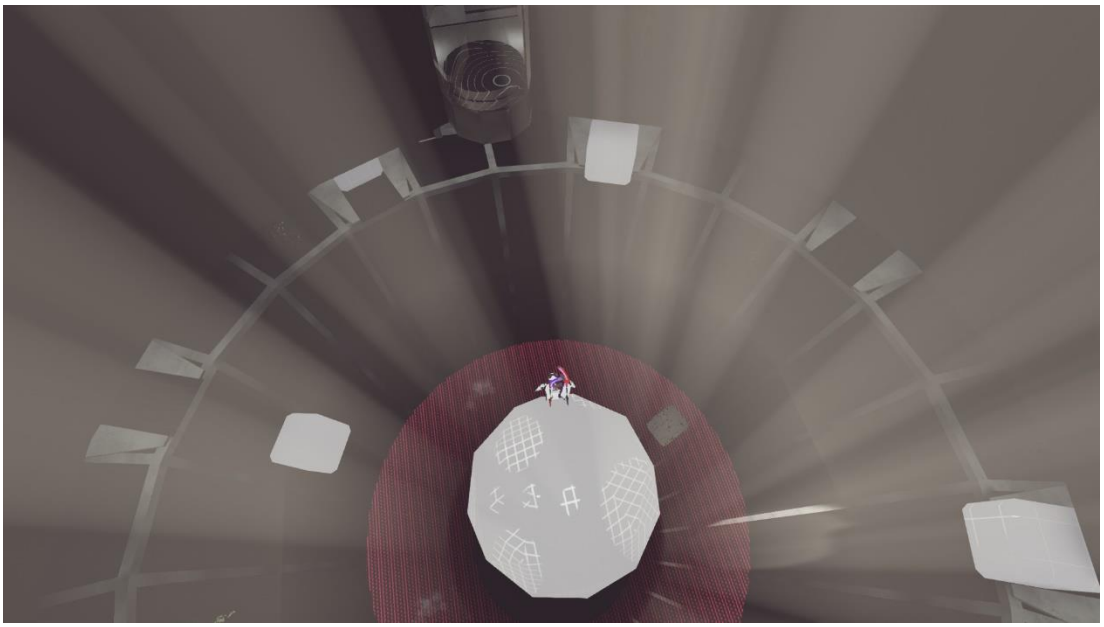

Figure 1: The level 2.11a Planet sets the player on the top of a floating magnetic sphere in middle of a round room from where player has to reach the edge of the room.

The same approach was also used in the other levels of the game which focused on emergence. During playtesting, players generally did find more emergent strategies in these levels compared to other levels. However, this also introduced the problem of dissatisfaction in some players when they were not sure if the solution they had found was the “correct” solution. The last chapter will discuss this observation further.

3.2 Large and Open Spaces

During the early development phases of the project, the game had several narrow corridors and small rooms that were used not only for traversal purposes but that had some action elements in them as well. This proved quickly to be a problem for the type of emergent gameplay that Plusminus enabled. Because of the unpredictable nature of emergence, a large portion of interesting emergent interactions happened suddenly without the player being able to anticipate them, especially while still attempting to learn the game system. In a game with a

third-person view like Plusminus, tight corridors can easily obstruct the camera view, making it more difficult for the player to look around them. While emergent behavior could still happen, the players had more trouble trying to locate and observe it. This also negatively impacted the progression of players' understanding of the game system and mechanics, which can be essential for the ability of players to form emergent strategies and gameplay [26].

Additionally, small rooms proved to be somewhat limiting for the magnetism system of Plusminus. It was harder to control which objects should affect which, and with what level of strength of the force. Objects would also get stuck in the corners of the room. Finally, related to the previous practice, small spaces had also less options for the players to find their own solutions to problems.

Larger and more open spaces worked better for both the mechanics of Plusminus and emergent gameplay. The scale of interactions was less restricted, and for example the objects could be launched for longer distances using magnetic forces. The players were also provided more resources for coming up with possible solutions or experimentation with the game mechanics. In an open area, players were able to see several separate puzzles at the same time, which at times encouraged them to combine the elements of different puzzles.

3.3 Experimentation as a Design Process

Emergence, as the name implies and as the earlier chapters have pointed out, is something that emerges from game systems, in contrast to something that is added as a part of the system. Therefore, it is difficult to design and create intentionally. When creating games with emergent gameplay, the emergent properties are often something that is only found after the first version of the system is implemented and possible to play and experiment with. Such experimentation and play with the game system are extremely valuable for game and level designers especially when designing for emergent gameplay since many forms of emergence is only found through such experimentation. In his presentation, Blow describes this process dramatically as seeking truth in game design [27]. According to him, play with the game system is an essential part of game design of the system since the nature of the system cannot be completely understood otherwise. Game systems may be able to display behaviors of systems which could not be anticipated or predicted but provide further insights into the mechanisms of the system.

For designing and prototyping levels for emergence in Plusminus, experimentation and playing around with the game mechanics proved extremely useful. Similar to how emergent behaviors occur when the player plays the game and experiments with the game system, emergence is also discovered when level designers experiment with the existing game mechanics and level elements. This emergence was then used as the base for several level concepts, such as *2.9b Sphere Rails, 2.10a Bridge,* and *2.11b Acrobatics*. As a part of experimentation, many more level

concepts were created this way which were either not included in the final game or were integrated in other levels or in the environment. The experimentation resulted also in the discovery of several issues and opportunities of improvements for the game mechanics during the development process. It also provides the level designers ideas on the kinds of emergent behaviors they should be aware of.

The intention for using emergent behaviors as the core of some level concepts was that it would highlight the flexibility and potential emergent behaviors of the game mechanics and provide examples for the player on how creative use of the game mechanics can cause interesting yet intuitive dynamics to occur.

3.4 Providing Examples of Emergent Behavior

As described in the discussion of the previous practice of experimenting with the game system in the level design process and utilizing emergence in level concepts, several levels of the game are based on discovered emergent behaviors that were not explicitly planned when designing the game mechanics. Such levels are for example *2.7b Sphere Launch* and *2.10a Bridge*. Use of emergence introduced a new challenge to the level design process. As Lundgren states, the ability to predict emergent outcomes in a game can be considered as a player skill [26], and therefore it may divide players based on their level of skill in making such predictions.

Figure 2: An example of a player-created chain of magnetic objects which allows the player to reach the elevated area in the level 2.10a Bridge.

While for some players the emergent dynamics used in the levels *2.7b Sphere Launch* or *2.10a Bridge* were intuitive and easy to understand, some players had more difficulties understanding them or discovering the emergent dynamics intended to be used in order to solve the level.

In order to overcome this challenge, the game was designed in a way that the player would be aware of such dynamics when entering the levels. For example, in the level *2.10a Bridge* player has to reach an elevated area in order to progress in the game. The level also includes a conveyor belt which is transporting magnetic objects from the elevated area and dropping them down in the area where the player first arrives. The player can reach the elevated area by creating a chain of magnets from the falling magnetic objects by setting them alternating polarities as seen in figure 2. However, this emergent strategy was difficult for many players to discover and understand intuitively.

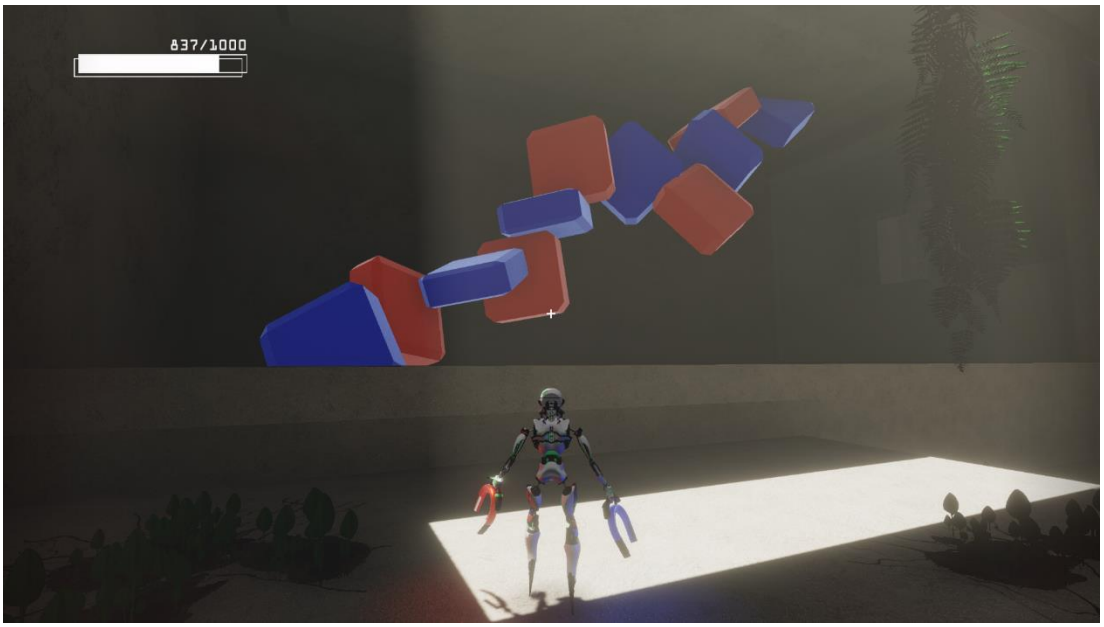

Figure 3: A designer-created example of constructing a chain of magnetic objects by alternating their polarities in the level 2.9a Traversal.

This issue is very similar with the basic idea of teaching the player the game mechanics in the beginning of a game. Player needs to form an understanding of the internal logic of the game system before being able to utilize the mechanics to solve problems. In digital games, planning how to introduce the player all the necessary game mechanics belongs usually to the domain of level design [17]. Similarly, when playing a level which involves an emergent dynamic which the player may not have seen before, the player needs to understand the game system in a deep enough level that such emergent dynamic would be reasonably predictable and make sense for the player. How games often help players to learn the game mechanics when they start playing

is to describe how the player can use the game mechanics, which can mean simply explaining what each controller input do, and to provide simple examples of the game mechanics in action.

Therefore, the level before, *2.9a Traversal* includes a ready-made example of a chain of magnets to help the player to be aware of the emergent strategy as seen in figure 3. Additionally, even if the player ignores the example at first, in the case they get stuck in the next level not knowing what they can do, they might start investigating the environment in further detail in which case the example, located close to the puzzle location, can draw their attention. The example chain was added later after playtesting had resulted in players not understanding how to solve the puzzle in *2.10a Bridge*, and introduction of the example helped more players to clear the level independently. Additionally, it also provided information about the emergent dynamic for players who would clear the following puzzle using other strategy than building the chain of objects as in the example.

3.5 Consistent Use of Game Mechanics

In his presentation, Smith introduced the concept of systemic level design, which describes the approach to implement the interactions between game objects so that the implementation is not instance specific but depends on the properties of the objects and a higher-level layer of abstraction which defines the interactions between such properties [20]. The gained benefit is that the interactions in the game world work in a natural and consistent way, which helps players to intuitively understand the internal logic of the game [25].

In Plusminus, levels and environments are designed in a way that support the player in understanding the internal logic of the magnetism mechanics by consistent and frequent use of the mechanics in the environment. Since magnetism is at the core of the game system, as many aspects of the levels and environments as possible were designed so that they would utilize the system in meaningful ways. For example, every door in the game is opened using magnetic forces, as seen in figure 4.

The aim of this kind of design approach is to make the player to use the game mechanics frequently, which supports the player in forming an intuitive understanding of the game system. It also serves a purpose for enabling more emergent gameplay. The more objects in the environment are using the game's magnetism system, the more players can discover interactions between the objects that designers might not be aware of. For example, if the player found a magnetic object and brought it near a door, they could use the magnetism mechanics to close the door only halfway instead of having it completely open or closed by placing the object between the doors and then attempting to close them. This could for example allow the player to pass through the door but prevent larger sized enemies from following them.

In addition to doors, the game environment in Plusminus includes other utility objects that use the game system in a similar manner. For vertical traversal, the player can frequently encounter elevators that use the magnetic system. In its simplest form, the elevator might be a metal plate the player is able to magnetize, located under or above another magnetic object which can be set to either push or pull the metal plate up or down, depending on the polarities of the object and the plate. Since the magnetic force system in Plusminus is compatible with the physics engine of the game engine, such elevators can be also used in combination with the basic jumping mechanic to give the player strong upward momentum, allowing the player to reach elevated areas. Additionally, combat against enemies in the game is also utilizing the physics engine, which allows the enemies to be damaged using any objects using magnetic forces or the general physics engine. For example, an enemy could be lured under an elevator and then the elevator can be made to descend on the enemy, causing damage to it.

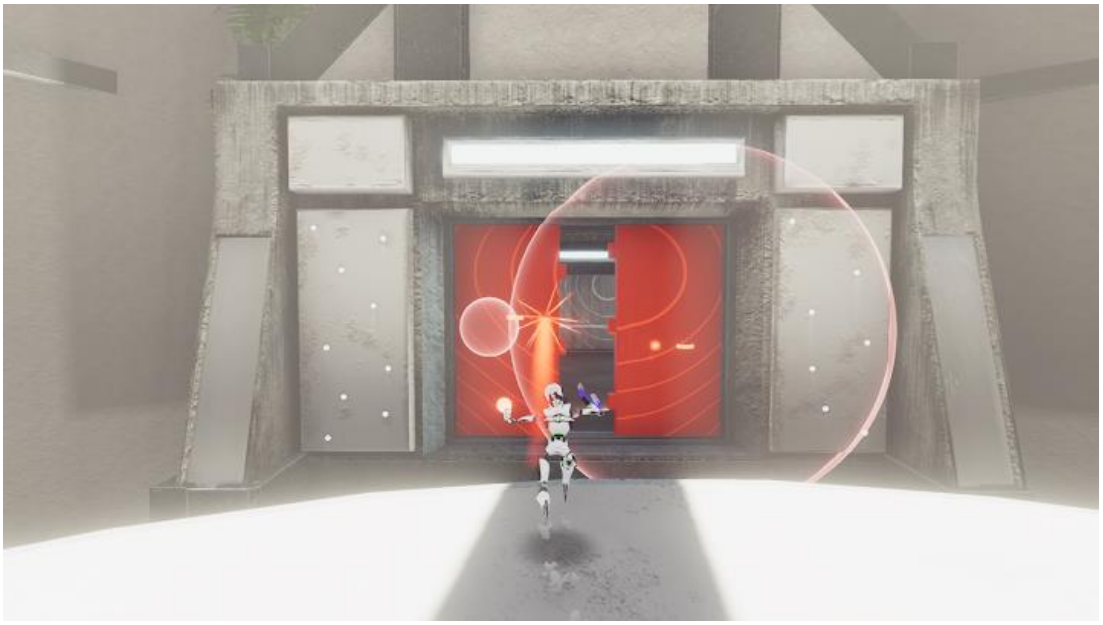

Figure 4: Doors in Plusminus work with the game's magnetic system. To open a door, the player needs to set the polarity of the two parts of the door with the same polarity in which case they apply a repelling force to each other, resulting in the door opening.

The game also includes pressure plates which are used to trigger events in the game environment, and which are magnetic and use the game's physics engine. Therefore, the player can use any magnetic object, including enemies or elevators, to activate the pressure plates. Similarly, certain level element that destroys the player character on contact can be used to destroy other magnetic objects and enemies as well. The game was planned to include also a train which would move using magnetism but having several magnetic objects on the train

which would be a dynamic object itself as well was beyond the limitations of the physics engine.

3.6 Available Game Objects

Gameplay in Plusminus revolves around the player controlling the magnetic properties of objects and using the forces of magnetism to move them around. These objects are often in the forms of basic geometrical shapes such as cubes and spheres, and function as single magnetic objects. The next section will discuss the level design challenges related to how these objects are made accessible for the player in the game environment. The section will discuss mainly puzzle levels that the player can solve using the provided objects.

Since magnetism is a core idea in the game, other types of interactions with the game system than manipulating objects with magnetism, except for jumping and moving, were omitted from the game. This, however, caused an issue with emergence. As all interaction between the player and the game system happens with the player playing and experimenting with game objects' magnetic properties, the presence of magnetizable game objects becomes crucial. If the player would be placed in an empty room, they would not be able to use the character's magnetism-related abilities at all since at least one magnetizable game object is required to interact with the magnetic forces. As discussed earlier, player can create magnetic fields on any surface, but unless the field is created on a metal object, it can only affect other objects but is not affected itself by magnetic forces. This became an important issue for the study of emergence in the game, since everything the player was able to do was dependent on how the game environment was designed and how the environment provided metal objects for the player to experiment on with magnetism.

The final version of the game allows the player to create magnetic fields on any surface, at least temporarily, but this functionality was added only after seven months of development. This reduces some of the environment requirements for magnetism as the player will be able to use these magnetic fields to manipulate a single magnetic object. Previously in the project, the player would need to have minimum two magnetic objects interacting with each other in order to use the magnetic forces at all. From the perspective of emergence, this introduced many limitations on the player's creativity and ability to experiment with the game system.

Additionally, it also created challenges for level design, since, for emergence, the game environment should provide the player a free environment which would allow the player to come up with creative solutions and dynamics that even the designers might not have anticipated. Magnetizable objects, however, are placed in the environment during the level design process, and how the objects are provided sets limitations on what is possible for the player to do. Therefore, the possibility space of each room is limited by what is made possible by the level design process. How can the level designer create environments that support

emergence, especially behaviors not predicted by the game designers, if they define what is possible in the level? The problem resembles the game design approach of scripting [3]. How to make the game support emergent gameplay if actions have to be exclusively defined by the designer?

The first problem of deciding how to provide the player with objects to magnetize was how to decide on the number of the objects. The number of available objects in the room sets limits on what the player will be able to do, as it sets the upper limit of objects used in possible solutions of clearing the room. For example, the player might be able to stack four spheres into a pyramid shape and reach a higher ground by jumping on the topmost sphere. However, such a stack would be more difficult to make with only three spheres instead. Additionally, playtesting observations for Plusminus implied that the number of objects in the room can set also player expectations, or a default player behavior, on how many objects they are supposed to use in their attempts to clear the level. If a room has two magnetizable objects, players may have tendency to think that they need to use two objects to solve the room. If room holds a supply of hundred magnetizable cubes, the player might be more inclined to use a large number of objects to solve the room, and therefore possibly dismiss ideas that require few objects. Naturally, it is not possible to clear all such factors that might limit creativity. Such limits set by the game or the level design can also even foster creativity [28]. However, for the purpose of this research an attempt was made in Plusminus to avoid suggesting single solutions for puzzles to the player in the levels emphasizing emergence.

The second problem related to how magnetizable objects are provided to players was the location where objects should be placed. Especially in previous versions of the game, moving objects had been difficult and tedious, so objects often had to be located close to where the player attempted to solve the level. However, the placement of objects sets again expectations for the player behavior, since placing the objects for example only in selected locations discourage players from experimenting with solutions in other locations. It seems that the same issues are present with object locations as with the number of objects. Scattering objects around the level will create the same issues with large number of objects provided, and too few objects are harder to reach which discourages experimentation.

Naturally, in most games, including Plusminus, object placement is not only a matter of puzzle design, but it also involves a narrative worldbuilding aspect. If the room is full of magnetic objects scattered around in the environment, can the player imagine a narratively coherent reason for why the objects are there? Incoherence of the game world can lead to weaker immersion and decrease the quality of the game experience. While this paper focuses on the relatively technical aspect of puzzle design, the narrative aspect is still acknowledged and considered when solutions are suggested.

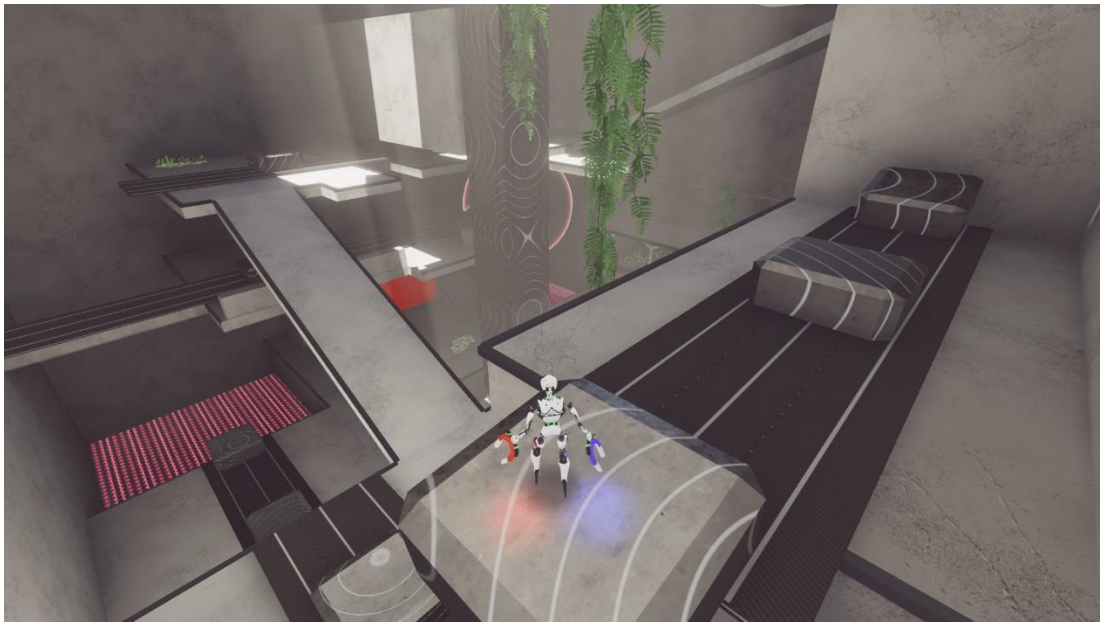

Figure 5: In the level 2.6a Tower, conveyor belts were moving a stream of magnetic objects across the entire level.

In Plusminus, these issues were attempted to be solved with a fluid number of game objects, which additionally would be automatically moved around the level. A fluid system instead of a fixed system clears most issues with number of game objects required or available in a level. In practice, the levels had conveyor belts that were moving objects which were created in regular intervals around the level as seen in figure 5. At the end of the conveyor belts, the objects would be moved into a contact with a red force field that would destroy them, effectively keeping the number of concurrent objects reasonable.

Based on playtesting observations, the solution worked well especially in larger levels where the players had several options for where to use the objects. Players seemed to experiment with solutions in varied locations, and they found new solutions which the development team was not aware of. While some players cleared the level with as few objects as possible, some players formed strategies which utilized large piles or stacks of objects well beyond the minimum necessary number of objects. Limitlessly generated objects also enabled new level of creativity of building large chains of objects which will be discussed further in the final chapter.

However, for emergent gameplay the game should provide more than only the objects that are intended to be used as solutions to puzzles and other challenges in the game. Because of the nature of emergence, level design for emergent gameplay should also focus on enabling the player to do behaviors that are not anticipated by the designers. Plusminus was attempted to be designed in a way that would allow players to discover new strategies and actions anytime, including outside of the puzzle or combat contexts.

For this purpose, the game environments are designed so that they include objects of which purpose might seem at first purely visual. However, often they are also a part of the game's physics and magnetism system and can be used for experimenting with the magnetic forces. For example, the level *2.2 Forking Path* includes iron pipes attached to the ceiling that the player can magnetize and attach objects to them. In the same level there are also small metallic cubes and tables that can be magnetized and some of them moved around. The level itself has the only purpose of traversal from previous level to the next. This introduced one early example of emergent strategies in the game, where the player could move a metallic cube from the level *2.2 Forking Path* to the level *2.3a Floor* and use the cube to reach an area the player would not be otherwise able to reach yet, skipping several puzzles and obstacles on the way.

Extra objects in the environment serve two other purposes as well. During the playtesting of Plusminus, some players had tendency to think that any objects in the environment, especially magnetizable objects, they might encounter had a purpose of being part of a puzzle, which can cause unnecessary confusion on what the player could do. Making the purposeless objects numerous and a part of the overall scenery of the world can help players to understand that these objects exist, and it is not necessary to find use for them. Additionally, it can help to link the narrative game world with the game system to make it seem like the magnetic system is a natural part of the game world.

The level design considerations relating to game objects concludes this chapter and description of the practices of increasing emergent gameplay with level design used in this research. In the final chapter, the development process of Plusminus is summarized and the results of the research are reflected on.

4 Discussion

In the final chapter, the thesis will first describe the process of making and iterating Plusminus and how the emphasis on emergence impacted the overall process, what was done right, and what could have been improved. The discussion will resemble the structure of a postmortem. Then the results of the emergent level design process and playtesting observations are analyzed. After that the final chapter will conclude the research project and suggest topics for future research.

4.1 Plusminus Design and Development Process

Making of Plusminus started in January 2018 as a part of a game project course at Aalto University with an initial project length of five months. The original team of six master's degree students, five of which were studying game design and production and one was studying audio design, was formed with a plan to create a game, at first with a different core mechanic using light instead of magnetism. After a month of work the original concept had still not proved itself and it was discarded, after which the idea of magnetism was formed.

The original idea of magnetism was already heavily emphasizing emergence, although the focus was slightly different. The concept was more focused on enemies and combat, which were also based on the magnetic system. Similar to the most recent version, enemies could be magnetized, which would cause them to repel or attract each other. The combat interactions would result in enemies creating large magnetic clusters which would emphasize the emergent behavior of the combined abilities of the enemies. For example, a flying enemy and a shooting enemy could create a cluster which would behave as a flying shooting enemy, resulting in a more dangerous enemy. On the other hand, attaching many wheeled enemies on a flying enemy could both prevent the wheeled enemies from moving and the flying enemy from flying, which would result in a less dangerous enemy. This type of system, however, required large efforts in enemy design and iteration, which the project could not afford since the basic game mechanics revolving around magnetism required already majority of the development time. While no decision was made to discard the idea, the current enemy design does not support that kind of emergence well and combinations of enemies seldomly result in interesting or meaningful outcomes.

While the concept of magnetism seemed to have more potential than the original concept of light, it had many game design and usability problems throughout the project and required months of efforts in iteration and playtesting before it proved its potential. After two and half months of development, a playtest session was organized with some local industry professionals. The prototype at that time had already first versions of puzzles and combat

situations based on magnetism ready, and the core idea for both were complete enough that they remained mostly the same for the rest of the project. The levels at the time, however, required heavy reworks, which required weeks of time because of inefficient workflows and technical solutions that prevented rapid prototyping and changes. At that time, the game was not emphasizing emergence as much, especially in its level design. During the next two months, the focus shifted towards more modular level design with emphasis on level dynamics and interactions with the magnetism system. Some levels were also designed to showcase the emergent behaviors enabled by the game system. The game mechanics had also some usability improvements. For example, visible magnetic fields were introduced during this time, which improved the usability and intuitiveness of the magnetic system greatly. The levels created during this period formed the spring version of the game, including the levels from *1.1 Anteroom* to *1.10 Final*. It was presented at the Spring Demo Day 2018 at Aalto University, which marked the end of the first phase of the project.

Originally there were no plans continuing the development after the spring. However, the university offered to hire two members of the team for the summer to continue working on the project and to submit it to the student game design competition of the CHI Play conference in fall 2018. During summer, the project shifted into more research-focused approach and emergence became the core concept. Levels for the game were also completely reworked in order to support better the game mechanics and emergent gameplay, and heavy focus was put also into iterating the game mechanics further, which altogether shifted the focus of the game slowly but eventually completely away from the creation of new art or audio assets and the story and narrative aspects of the game. Since the resources of the team were very limited, with one programmer and level designer working on the game, such change of focus was necessary. During summer, the game's emphasis on combat was also reduced and more levels were created for the purpose of showcasing the game mechanics in puzzle formats.

During summer, several important changes to the game mechanics were introduced. The upper limit of how many different magnetic objects could have an active magnetic field at the same time was experimented on before the game settled with removing the limit completely. The most important change was, however, that magnetic fields could be placed on any surfaces instead of only metal objects. Magnetic fields placed on the non-metal surfaces would not, however, assign polarity on the surface object and the field would disappear after short time. This allowed more types of interactions and provided new level of player freedom when all actions were not completely depending on designer-provided metal objects, seen in figure 6. It impacted emergence in new ways that increased the overall occurrence of emergent behavior.

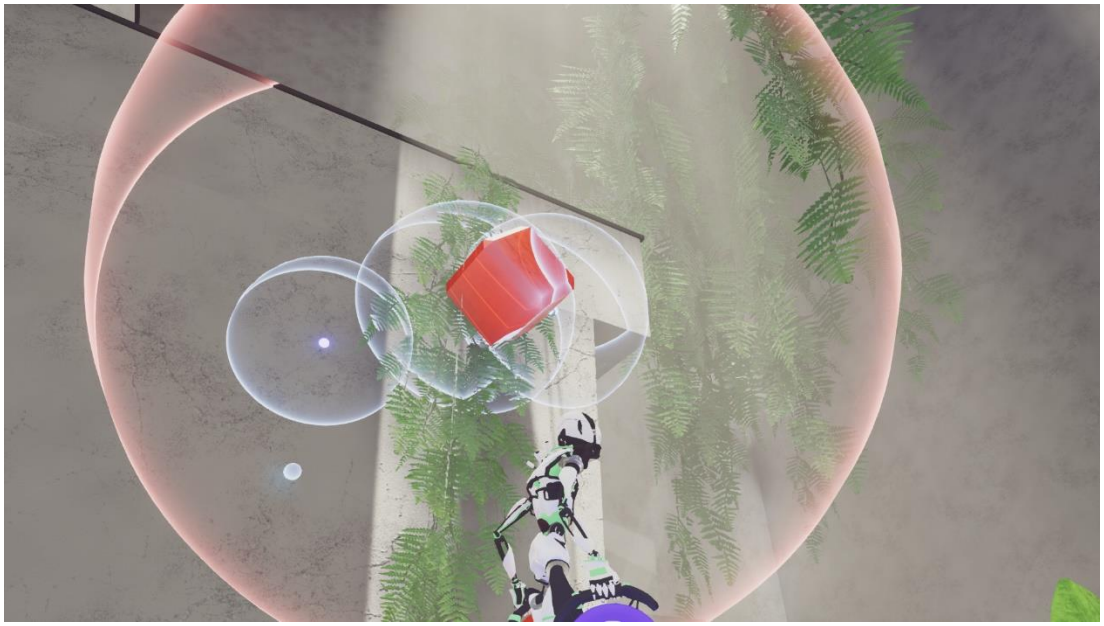

Figure 6: Allowing player to attach temporary magnetic fields on any non-magnetic surfaces greatly increased player freedom and creativity in terms of control of magnetic objects.

During the three-month summer phase of the project, the level structure of the most recent version at the time of publishing this thesis was created and most of the levels from *2.1 Tutorial* to *2.14 Final* were finalized. The game was submitted together with a research paper on emergent gameplay and physics [29] to the CHI Play 2018 Student Game Design Competition, where it won the jury's choice award. After August 2018 the active development ended.

Plusminus was submitted to the Experimental Gameplay Workshop in Game Developers Conference 2019, and in January it was chosen in the game lineup of the event. During that time, the game was mostly polished without any major changes. Plusminus got comments at the event for its game mechanics and system. For example, Hunicke, the host of the event, recognized Plusminus as "a dynamic game" which focuses on simulating systems in a level of detail that can provide players opportunistic learning possibilities [30]. After the game was presented at the event in March 2019, the development halted again, and the game remained in the same state as it is now at the time of publishing this thesis.

The success of the project could be addressed to several factors of its development. The concept of magnetism had enough both novelty and simplicity for the game to seem new and original while easy to understand and not alienating. However, it would be misleading to claim that this was due to the original idea of magnetism. Magnets are not uncommon theme in video games, and for example searching games with the keywords "magnet" or "magnetism" in the game market platform Steam provides more than two hundred games. While in some of the games magnets play only a minor role, the number of games that have magnetism as their core focus is not trivial. However, the level of commitment to the magnetism-based game

mechanics, the balance between realism and simplicity, and the efforts put in polishing the player interactions and responsiveness may have helped Plusminus to stand out. During playtesting sessions and other evaluations from players and industry professionals, the game got often praise for its novelty and originality.

The emphasis of emergence in the project was also an important factor that helped the game to make an impression. Emergent gameplay seems to be suited well together with physics-based gameplay since the game rules which are based on the laws of physics enable emergence and make it a natural occurrence, and on the other hand emergence enhances the use of physical laws in the interactions between the player and the game system. Consistent use of the emergence-focused game mechanics in level design, game environment, puzzles, and combat highlighted the aspects of the game that players found the most interesting and distinctive.

For the scale of the course project the game originally started as, it was a result of ambitious goals, which the project did get comments and feedback for. However, the goals were mostly met because of the commitment of the team to the project, confidence in the capabilities and experience of the team, and successful scoping and prioritizing efforts. The game mechanics and general gameplay required large efforts in iteration, playtesting, and polishing, and the time had to be taken from the other aspects of the game. Especially during summer, after the first five months of development, the shift of focus almost completely on to gameplay allowed the game to have one strong point around which the rest could be built later.

However, the project faced challenges. During the spring development phase, the game had issues with the level design workflow, which prevented rapid iteration of levels. When the game was tested for the first time in a larger playtesting session with industry professionals, the game got feedback especially for the confusing level structure and the suitability of levels in relation to the game mechanics. Afterwards the necessary changes in the levels took also longer than expected. The issues may have been also avoided if the level prototyping and testing would have been started earlier in the level creation process. After the feedback session after four months of development, the level creation process was eventually started over with a more modular level framework with focus on the ease of prototyping and editing.

The iteration of game mechanics continued throughout the project, and the basic player interactions were changed as late as during the last month before CHI Play conference submission in the end of August. While the changes were generally advantageous for the gameplay of Plusminus, the time was cut from other aspects of the game such as worldbuilding and the narrative, which may have impacted the motivation and commitment of the team members whose roles it impacted the most. Additionally, for the level design process in summer, several level concepts and completed levels had to be discarded late in the development process since some basic player interactions or properties of the game system changed resulting in the levels not being conceptually possible to clear or play in the changed

system. This cost time for the game that was allocated to level iteration and quality assurance, compromising the player's experience when playing the levels.

Finally, a crucial challenge during the summer development phase was a lack of playtesting opportunities. The size of the team was reduced to two, and because of the summer season there were less people present at the university, where the game was mostly being developed at, which made it difficult to find players to test and evaluate the game. Because the development was especially focused on game mechanics and emergent gameplay during this time, playtesting was especially important. Many design discussions and issues in summer could have been possibly solved through playtesting, since the perspective of developers during a long project such as Plusminus can get stale, and it may become difficult to see how the game is from the perspective of a player. However, no solution was found for the playtesting issue in the end, which may have compromised some of the game's quality.

4.2 Results and Player Observations

The next section will evaluate the success of the emergent level design process through the feedback received and observations made in playtesting sessions during the development time of the project. The topics discussed include problems in teaching the game mechanics to the players, how players differed in terms of emergent gameplay and its enjoyment, and the successes of increased emergent strategies used in the levels designed to support emergence.

Before discussing the difficulties players had learning the game mechanics, the game system rules will be shortly summarized. To understand the game mechanics, the players do not need deep understanding of the physical properties of magnetism. The basic properties of magnetism the game focuses on are:

- Magnetic properties can be of either positive or negative polarity, which are color coded as red and blue (see figure 7).
- When interacting, objects of same polarities apply repelling force on each other.
- When interacting, objects of opposite polarities apply attracting force on each other.

Additionally, the game simplifies magnetism further by additional rules:

- A metal object can be magnetized, which means that a magnetic polarity is applied on it.
- A magnetized metal object can have only one polarity.
- When a metal object is magnetized, a visible magnetic field is rendered around it and it has a color corresponding the polarity of the object (see figure 7).
- Magnetic objects are interacting when their magnetic fields are in contact with each other.

Figure 7: Metal objects can be magnetized with either positive or negative polarity, color coded as red and blue. Magnetized objects have a transparent field around them indicating the range of the magnetic field.

Plusminus attempted to model the magnetism system after the real world magnets to a level of realism that was still simple enough for the player to not need to know any technical details of how magnets function, because such systems can make it easier for players to learn and understand intuitively the internal logic of game systems [3]. However, some players still had trouble understanding how magnets worked in the game because they did not attempt to apply the knowledge of magnets they had from the real world into the game. While they understood the concept of polarities and how magnetic properties of different polarities interact in the real world, they still had to learn it separately in the game world. It seems that even if a game follows the natural logic of the real world, making players to understand and trust that the real-world logic can be applied to the game world seem to require still additional efforts. The assumptions of players may tend to be that the logic of game systems is inherently separate from the real world and that it needs to be understood separately. Therefore, it may be that realism or realistic interactions alone should not be depended on when making a game to be intuitive and easy to learn, but efforts are still needed in introducing and teaching the game mechanics to a player.

Especially during the earlier phases of the project, the players' lack of understanding the game mechanics was an obstacle for emergent gameplay. Emergence requires players to have deep enough understanding of the game system and its internal logic so that it is possible to apply that understanding in practice by experimentation. This may have been a reason why emergent gameplay was less common in earlier versions of the game compared to the later versions, since while the game mechanics on which most of the emergent gameplay occurring was based

was implemented early in the project, most gameplay changes afterwards had the purpose of making the game interactions and logic easier to understand.

Lundgren et al. argued that being able to predict the outcomes of emergent systems is a player skill, and player's appreciation of opportunities for emergent gameplay may depend on the level of such skill of the player [26]. The playtesting results of Plusminus supported this claim. Players differed greatly on how well they could utilize the emergent strategies provided by the game system, which often also correlated with how much they enjoyed finding and using such strategies. The players would be spending more time experimenting with the mechanics also outside of puzzle or combat situations and were less concerned of if their actions made them progress in the game or not. When the players were interviewed after having played the game, moments of discovery and successful applications of emergent strategies were commonly mentioned as memorable moments while playing the game. Players who struggled more learning the game mechanics at first were also utilizing less emergent strategies later in the game as well.

How the players' appreciation of the design approach focusing on emergent gameplay differed was not always related to their capabilities in playing the game or understanding the game system, but it seems that the personal preferences of players also impacted on how they enjoyed the levels which emphasized emergence. In Plusminus, the level progression is divided in two paths after the level *2.5 Hub*, and while both paths need to be cleared in order to progress in the game, players can choose in which order they clear them. In terms of emergent level design, the path from *2.6a Tower* to *2.11a Planet* is emphasizing heavily on emergent gameplay, while the path from *2.6b Experiment Room* to *2.11b Acrobatics* is designed with an approach resembling more the earlier concepts of emulation [22], progression structure [21], and scripting [21], which are used often as the opposite examples of emergence. This structure of dividing two distinct level design styles provided interesting observation on players' reactions to each level design approach. Overall, there was no significant difference on which path was more appreciated on average, even though such difference could have emerged from larger groups of players. However, players seemed often to prefer one path or the other. Players who preferred the path with the levels heavily emphasizing emergence also appreciated more experimenting with the game system and finding their own emergent solutions for the puzzle problems, while players who preferred the other path experimented less and enjoyed more challenges where the directions where clearer and less ambiguous. The latter players displayed some degrees of confusion and frustration at times when solving a challenge on the emergent path, because they were not sure if the way they solved the puzzle was "the correct solution". The levels are intentionally designed in a way that there is ambiguity on around which solution the level may have been initially built to encourage players to use different strategies. However, it may be that for some players, the enjoyment of solving a puzzle comes from coming to understand the puzzle at the level of designer intentions instead of only finding a solution to get around the problem.

At times the opportunities for emergent gameplay introduced also usability problems to the game. In levels *2.7b Sphere Launch* and *2.8b Sphere Traversal*, some players formed an emergent but suboptimal strategy in order to solve a puzzle, and because it may have been the only strategy they are aware of or because they assumed that alternative strategies would not be more efficient, the players would not change their strategy. This caused some issues where the suboptimal strategy would make challenges considerably more tedious or difficult resulting in player frustration.

Overall, it seems that purely emergent approach on game design, or at least puzzle design, may not be ideal for a game and might turn down some players. Players' differences in capabilities of understanding such emergent system and willingness to experiment with it may vary and impact the game experience. Additionally, players' personal preferences might also impact on how much they appreciate the opportunities to come up with emergent strategies. However, this does not mean that such games should not be designed, since games do not necessarily need to appeal to every player and focus on a smaller group of players can be a successful strategic game design decision [31].

The methods of designing levels for emergent gameplay described in the chapter three generally succeeded in increasing the amount of emergent gameplay occurring during playtesting. Levels designed with the problem-centered puzzle design approach provided players multiple options for solving the level, especially in levels *2.10a Bridge* and *2.11a Planet*, and some of the strategies were not thought of by the development team before. To compare, emergent strategies were much less common in levels where the goal was more complex and required more specific actions, such as *2.7b Sphere Launch* and *2.9b Sphere Rails.* Additionally, the use of larger and open rooms allowed players to observe better the consequences of their actions, allowing them to understand the game mechanics better and appreciate emergent behavior when it would happen unexpectedly.

Levels which were created from level designer's experimentations of the game system did generally not display more frequent occurrences of emergence compared to other levels. Such levels are for example the *2.9b Sphere Rails* and *2.8b Pool*. However, such experimentation improves the designer's understanding of the game system and the potential emergent behavior, which can be a valuable asset in level and game design and in quality assurance in the form of being able to anticipate better game-breaking behaviors. Additionally, the experience gained from the experimentation carries to the later design of other levels as well, which may have impacted the occurrence of emergence in such levels. Finally, the designers' knowledge on existing emergent behaviors in the game enabled levels to be designed around such behaviors, which provided the player examples of emergence in the game system and improved their understanding and capability of forming their own emergent strategies.

The biggest impact of a single level design choice on the occurrence of emergence was related to the availability of magnetizable game objects in the scene described in the third chapter.

Removing the limitation of fixed number of game objects per level increased the player freedom and creativity and enabled more emergent strategies. For example, in level *2.6a Tower*, players could create a long chain of magnets filling the entire level consisting of more than hundred objects, as seen in figure 8, even when clearing the level only requires minimum of two magnetic objects.

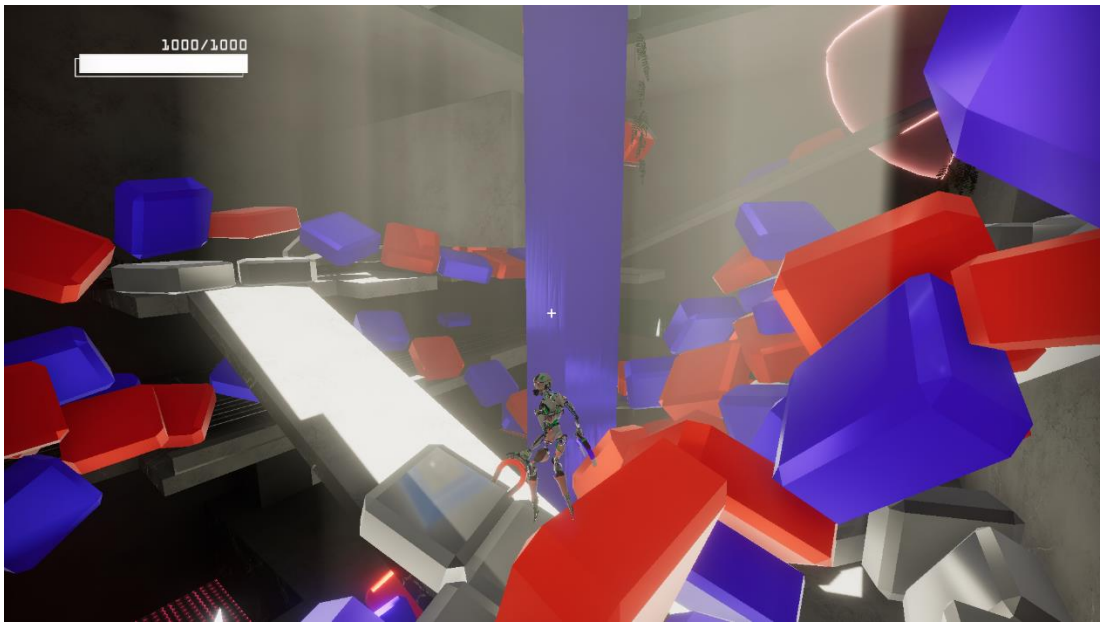

Figure 8: The attempts on removing limits of the availability of game objects in a level increased the level of emergence and player creativity significantly.

Even though later changes to the game mechanics did remove the possibility of constructing such chains, the levels which utilized the removal of fixed number of magnetic objects displayed high occurrence of emergence. Because the reasons and arguments for removing the limit was specific for the game system of Plusminus, like described in the third chapter, it may not be directly applicable to other games. However, it also demonstrates that supporting and enabling emergence and removing restrictions on the actions of players may often require solutions tailored for the specific game system instead of more universal considerations. For level design, it can be useful to identify any possible limitations the level design might intentionally or unintentionally impose on players and experiment with solutions that remove such restrictions.

4.3 Conclusion

In the second chapter, the thesis examined the concept of emergence based on earlier research, which was used to form and employ strategies, described in the third chapter, in the level design processes of the Plusminus project. This chapter discussed the results of the strategies used. Finally, the chapter will reflect on if the results supported the main thesis introduced in the first chapter:

> *Designing games for emergence does not involve only game system design but requires also considerations in level design, and that level design may have significant impact on how emergence occurs in a game.*

As discussed earlier in this chapter, the occurrence of emergent gameplay seems to depend on how well players understand the game mechanics and the game system. Players with higher level of capability of doing so employed more emergent strategies in their play than players who struggled with the game mechanics. Efforts put in introducing and teaching the game mechanics to the player through level design seemed to increase the occurrence of emergence. Additionally, attention in level design for providing the player examples of possible emergent behavior in the game helped players to experiment more with the game system and to be aware of the possibilities for emergent gameplay.

As described in chapter three, the way levels were designed impacted on the occurrence of emergence in Plusminus. The original size and shape of levels, before it was fixed later, made it more difficult for players to appreciate emergent behaviors in the game, which reduced the overall occurrence of emergent gameplay. Careful analysis, especially from the perspective of game mechanics, of the other limitations level design of Plusminus imposed on players also resulted in approaches that increased the level of player freedom and creativity allowing more emergent gameplay.

The results demonstrate that designing games for emergent gameplay does require considerations in level design, which otherwise might decrease the possibilities for emergent behavior in a game. The design methods used in the levels of Plusminus did also increase the occurrence and possibilities of emergence.

However, because of the vague nature of what is level design when discussing broader types of games and game genres, the findings should not be applied to games that are drastically different from Plusminus without caution. It may be also useful to confirm the results of the research with more systematic approach to playtesting with larger group of testers. The occurrences of emergent strategies are not rare, but it does not happen for each player, which makes it more important to have large number of players.

For future research, it may be beneficial to analyze the connection between emergence and level design for other types of games which differ from Plusminus, especially game genres for which the level design processes are different. The impact on the physics-based game mechanics on the types of emergence in Plusminus was significant, and the same principles may apply differently to games without the use of physics. This thesis suggests an area of study which would require much more research: the impact of level design in emergent gameplay. Further research could attempt to pinpoint in more detail what kind of level design supports emergence and what approaches can be used in different types of games to improve emergence in games.

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Appendices

Appendix A

List of Levels

Name	Version	Description
1.1 Anteroom	May 31st 2018	A short walking path the player takes before they get access to the magnetization tools.
1.2 First Arena	May 31st 2018	An introductory room with a simple magnet puzzle and a combat scenario.
1.3 Tutorial	May 31st 2018	A sequence of simple puzzles where the player is required to magnetize objects with the correct polarities. Ends in a combat scenario against three basic enemies.
1.4 Pits	May 31st 2018	A combat level with several enemies on a pillar without walls. Player is able to push enemies off the pillar.
1.5 Sphere	May 31st 2018	A combat level with enemies and a large metal sphere which can be moved freely around the level.
1.6 Floor	May 31st 2018	A combat level with several enemies. The floor of the level is metal and can be magnetized.
1.7 Bridge	May 31st 2018	An action level where player has to progress through a long path involving different scenarios with small vertical magnetic pillars which can be raised or lowered to floor level.
1.8 Pillars	May 31st 2018	A combat level with flying enemies where the floor of the room is formed of small magnetizable pillars that can be raised or lowered to the floor level.
1.9 Aerial	May 31st 2018	A combat level where the floor of the level is a magnetic launcher launching the player upwards.
1.10 Final	May 31st 2018	A combat level against a large magnetizable boss enemy and a slow stream of generated enemies.

2.1 Tutorial	March 18th 2019	A puzzle level with two puzzles where the player has to use repulsing and attracting magnetic forces. Ends in a combat scenario against three basic enemies.
2.2 Forking Path	March 18th 2019	Traversal path which provides the player the options of progressing to 2.3a Floor or 2.3b Conveyor Belts level.
2.3a Floor	March 18th 2019	Sequence of puzzles and combat scenarios involving magnetizable floors or ceiling.
2.3b Conveyor Belts	March 18th 2019	A puzzle level involving conveyor belts and upwards traversal.
2.4 Pits	March 18th 2019	A combat level with several enemies on a pillar without walls. Player is able to push enemies off the pillar.
2.5 Hub	March 18th 2019	A large level including several exits. Two exists accessible to the player from the beginning but the player needs to solve a puzzle for both before passing. Gives the player the choice of progressing to 2.6a Tower or 2.6b Experiment Room. Includes the entrance to 2.12 Train, which is not accessible to the player at first.
2.6a Tower	March 18th 2019	A puzzle level that involves a tall magnetizable rotating pillar at the center of the room. Ends in a combat scenario with several enemies.
2.7a Traversal	March 18th 2019	A traversal level which includes a basic puzzle which requires the use of magnetism.
2.8a Pool	March 18th 2019	A puzzle level with the exit located in the bottom of a pool filled with magnetic objects the player needs to somehow remove.
2.9a Traversal	March 18th 2019	A traversal level which includes a basic puzzle which requires the use of magnetism. Includes an example of a chain-building dynamic.
2.10a Bridge	March 18th 2019	A puzzle level where player needs to access an elevated area. Includes a conveyor belt which drops metal objects from the elevated area to the starting area.
2.11a Planet	March 18th 2019	A puzzle room with a large floating metal sphere at the center the player falls on. Player

		needs to access walls of the room without falling.
2.6b Experiment Room	March 18th 2019	A traversal level filled with examples of using magnetism to give momentum to small spheres.
2.7b Sphere Launch	March 18th 2019	A puzzle level where the player needs to control the momentum of a large magnetic sphere with magnetism. Ends in a combat scenario where the player can use an extremely large magnetic sphere to damage enemies.
2.8b Sphere Traversal	March 18th 2019	A traversal level.
2.9b Sphere Rails	March 18th 2019	A puzzle level where the player needs to move a sphere along a path marked with rails.
2.10b Sphere Combat	March 18th 2019	A combat level where the player can use a magnetic sphere to damage enemies.
2.11b Acrobatics	March 18th 2019	A puzzle level involving magnetic pillars that can be pulled from or pushed inside the walls of the room. Involves a large rotating magnetic pillar in the center of the room.
2.12 Train	March 18th 2019	A traversal level where player needs to move a magnetic train from the beginning of the level to the end.
2.13 Aerial	March 18th 2019	A combat level where the floor is a magnetizable launcher launching the player upwards.
2.14 Final	March 18th 2019	An ending level.